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ALTERNATIVE OFF-OIL SCENARIOS

FOR ONTARIO:

Results Obtained from Statistics Canada

Housing Model.

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1.0 INTRODUCTION

1.0.1 This paper, in response to the recently published National Energy Program, presents three alternative off-oil scenarios for the Ontario space heating market. The three off-oil scenarios consist of a 35% and 65% conversion rate of pre-1971 built houses to gas, electricity or electric-oil hybrid heating for the 1982-86 and 1987-1991 periods respectively. The results are compared in 1986 and 1991 against a "business as usual" or baserun for fuel oil savings. The results show that the reduction in fuel oil usage as a result of a government off-oil program could be 8 million barrels per year by 1986 and 15 million barrels per year by 1991. This translates into a cumulative fuel oil saving over the decade 1982-1991 of 76 million barrels of oil. These savings are over and above those achieved in the baserun which represents the natural evolution of the housing stock.

1.0.2 These results are drawn from the "Household Model" developed by the Structural Analysis Division, Statistics Canada. The "Household Model" is a simulation framework and related data base of the Canadian housing stocks, residential construction and end use articulation of energy consumption in the residential section. The purpose of the model is to provide an analytical tool for evaluating a variety of residential energy conservation strategies including thermal

retrofitting and the introduction of new building performance standards,the possibilities for fuel substitution afforded by equipment retrofitting, and the impact of new technologies for space conditioning with respect to impacts on residential energy requirements over time. The choice of Ontario was arbitrary; similar calculations can be performed for British Columbia, Quebec, and the Maritime and Prairie regions. These scenarios are not to be construed as forecasts nor in fact accepted policy alternatives. They are, however, to demonstrate the capabilities of the "Household Model" in performing time structured fuel substitution strategies to examine the impact of the structural requirements of the space heating market.

1.1 Background

1.1.1 The Household Model is an independently operating block of the Long Term Model(LTM) currently under development by the Structural Analysis Division. Although the Household Model parameters and reports have been designed for independent operation the calculations will eventually be incorporated as a block in the LTM. The Household Model is structural rather than behavioural. That is, the universe of Canadian houses is described in great detail using data from the census, the ENERSAVE survey, and the CMHC housing data. This structural picture is then allowed to evolve according

to user specified scenarios. Periodic energy aggregations then provide snapshots of energy usage levels through a twenty five year time horizon.

1.2 User Interface

1.2.1 The model inputs have been set up in tabular form with row and column identification so that data entry is controlled and documented as it enters the input stream to the model. Several ancillary computer programs have been written to translate the user's scenario into the detailed time series of matrices required by the model. Some of these programs play the role of data organizer both eliciting data from the user and setting up the structures needed by the model. Other programs extrapolate trends and create the input time series which can then be edited in detail.

1.3 Organization of the Paper

1.3.1 The block structure of the model is described in section 2 together with a description of each block as to function and user input options. Section 3 outlines various ways of using the model including the technique involved in producing the off-oil projections. Section 4 and 5 detail a set of scenarios run through the model and explicates the results using graphs and tables from the model. Following the paper an appendix is included that details some

assumptions implicit in the energy demand calculation.

2.0 HOUSEHOLD MODEL STRUCTURE

An overview of the model structure is depicted in figure 2.0. The model consists of six major calculation blocks:

2.1 1971 base housing stock;

2.2 Demolition of base housing stock;

2.3 Thermal retrofit of base housing stock;

2.4 Heating equipment retrofit of base stock;

2.5 New housing (Post 1971) requirements;

2.6 Aggregate energy requirements for space and water heating in the total housing stock.

The main input and output variables are listed in figure 2.0 and the time loop shows that block 2.1 is performed initially and remains outside the loop, whereas blocks 2.2 to 2.6 are within the time loop and so represent evolution of the variables over the twenty five year simulation time horizon. These blocks are described in more detail:

The sections that follow describe the blocks, inputs and outputs shown in figure 2.0.

2.1 1971 Base Housing Stock

This block reads and interprets historical and parametric data needed to form a base for the future scenario.

Inputs here include those described under subsection 2.1.1 to 2.1.5.

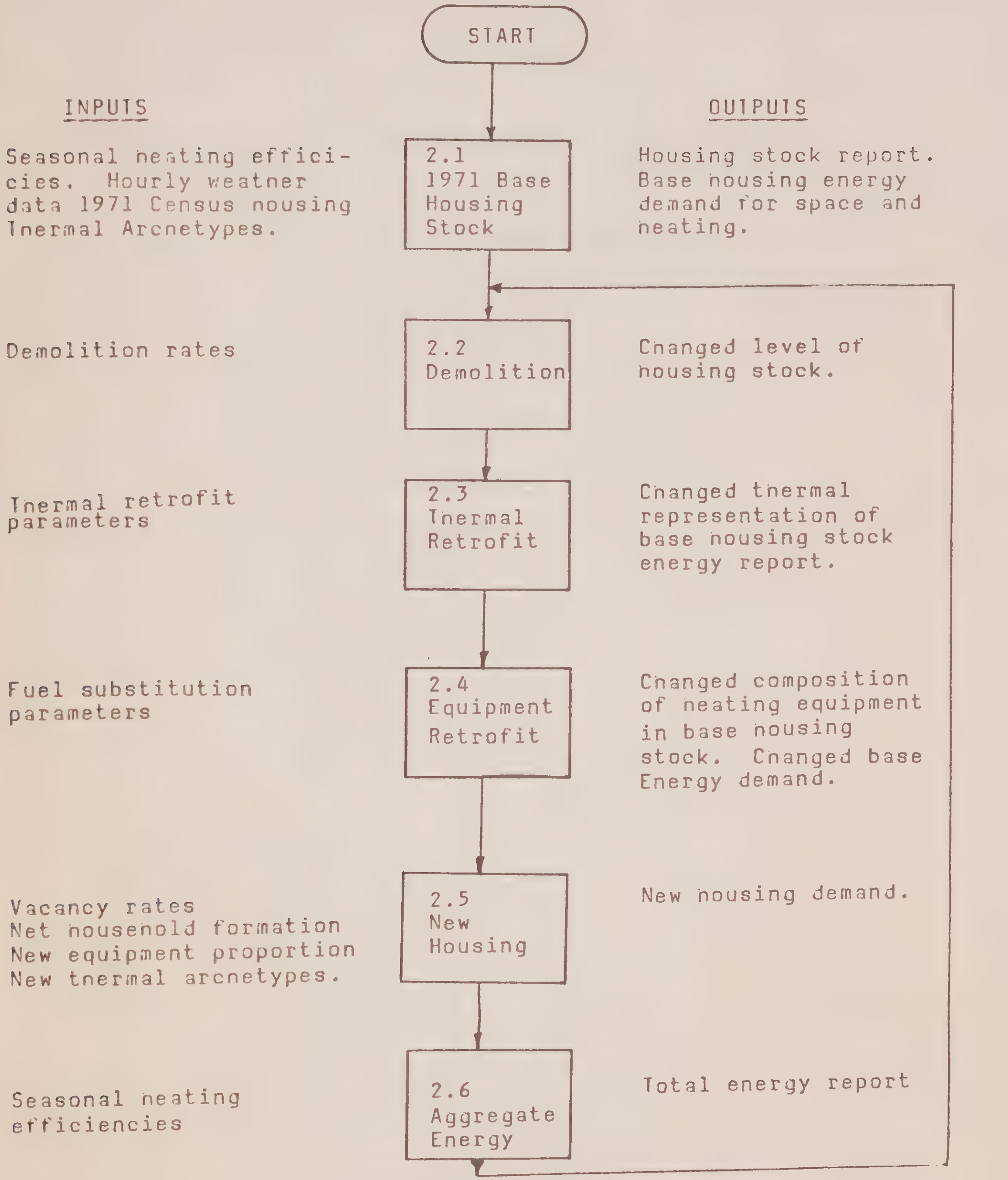


FIG. 2.0 HOUSEHOLD MODEL STRUCTURE

2.1.1 1971 Base housing stock which is stratified by type of housing, period of construction and heating equipment class.

Housing Type:
1. Single detached (this includes mobile home);
2. Semi detached and duplex;
3. Row houses and single attached;
and 4. Apartments.

Period of Construction:

built
1. 1920 or before
2. 1921-1945.
3. 1946-1950.
4. 1951-1960.
5. 1961-1965.
6. 1966-1970.
7. in 1971.

Heating Equipment Type

1.	Water Oil	(WO)
2.	Water Gas	(WG)
3.	Water Solid	(WS)
4.	Hot Air Oil	(HO)
5.	Hot Air Gas	(HG)
6.	Hot Air Solid	(HS)
7.	Electricity	(this includes both baseboard heaters and furnace) (EE)

8. Space Oil (SO)

9. Space Gas (SG)

10. Space Solid (SS)

Water refers to hot water or steam, hot air means forced air with ducting and space means point of use equipment such as oil space heaters or wood stoves. Allowance has been made in heating equipment categories to include seven more heating equipment types which reflect the use of hybrid technologies.

These are:

8) Saskatchewan House (SH)

9) Heat Pump - Oil (PO)

10) Heat Pump - Gas (PG)

11) Heat Pump - Electric (PE)

12) Heat Pump - Solar (PS)

13) Gas - Solar (GS)

14) Electric Solar (ES)

The Heat-Pump categories could also reflect conventional electric & oil and gas hybrids. The only difference in the calculations would be in the seasonal heating efficiencies used.

2.1.2 The <u>thermal characterization</u> of the base housing stock was obtained from Energy Mines and Resources (EM&R) ENERSAVE data. A cross tabulation of three house component (ceiling, wall and basement wall) insulation levels by period of construction of the dwellings gave distributions of twenty thermal archetypes in the stock.

2.1.3 The <u>physical characteristics</u> of the housing stock were obtained from Canada Mortgage and Housing (CMHC) 1969 material input survey. These include area sizes for the following house components by the four types of dwellings described earlier:

1) Wall;
2) Ceiling;
3) Basement Wall;
4) Window;
5) Doors;

and 6) Average Liveable Area.

These parameters are time dependent and so can be changed to reflect an increase or decrease in average dwelling sizes.

2.1.4 Weather tapes were obtained for 13 locations in Canada from the National Research Council and give hourly ambient temperatures and solar heat gain factors. These data were sampled every four hours and were population weighted to reflect the five regions of Canada average weather conditions. Four hourly data enables the model to perform dynamic heat load analyses necessary to investigate the impact of hybrid electric or heatpump technologies. This will be described in more detail later.

2.1.5 For the base stock an initial table of seasonal heating efficiencies by heating equipment type and fuel type is specified as given in the following table: These efficiencies reflect average seasonal heating efficiencies, and can be changed in future periods to reflect increases in efficiencies. The energy output is particularly sensitive to changes in overall seasonal heating efficiencies and so must be considered within this modelling framework as one of the more important determinants of total energy demand.

EFFICIENCIES

	OIL	GAS	FLE-RES	ELE-HP	ELE-MOT	SOLID	LPG
WATER-OIL	55	0	0	0	100	0	0
WATER-GAS	0	60	0	0	100	0	0
WATER-SOLID	0	0	0	0	100	55	0
HOTAIR-OIL	55	0	0	0	100	0	0
HOTAIR-GAS	0	60	0	0	100	0	0
HOTAIR-SOLID	0	0	0	0	100	60	0
ELECTRICITY	0	0	100	0	0	0	0
SPACE-OIL	55	0	0	0	0	0	0
SPACE-GAS	0	0	0	0	0	0	60
SPACE-SOLID	0	0	0	0	0	55	0
SASK HOUSE	0	0	0	0	100	0	0
HP-OIL	55	0	100	200	100	0	0
HP-GAS	0	60	100	200	100	0	0
HP-ELE	0	0	100	200	100	0	0
HP-SOLAR	0	0	0	200	100	0	0
SOLAR-GAS	0	60	0	0	100	0	0
SOLAR-ELE	0	0	100	0	100	0	0

2.1.6 Output from block 2.1 includes a base housing stock report and a 1971 base housing energy demand for space and water heating.

2.2 Demolition

2.2.1 Inputs to block 2.2 include user constructed demolition rates, another time dependent variable which creates changes in the old housing stock levels. The demolition rates are specific to the type of house and period of house construction.

2.2.2 Output from block 2.2 includes a changed level of base housing stock report.

2.2.3 Demolition can be regarded as part of the background scenario. However, simulation results can be very sensitive to the demolition rates. In most impact studies the demolition values are not crucial so long as they do not distort the stock distribution by either completely ignoring or greatly over stating natural attrition. For example, the assumption that no demolition occurred, or that all demolition rates are set to zero, would seriously distort the model's energy outputs. The older stock which was not destroyed has poor insulation levels; in fact, it is so much poorer than newer stock that the dwelling heat loss turns out to be a strongly non-linear function of dwelling age. Retrofit action occurring on this older stock would give the erroneous impression that large energy savings were being effected through retrofit.

2.2.4 We have derived a reasonable procedure for the estimation of demolition rates; inputs to the procedure are:

1) A constant demolition rate for all stock older than twenty years;

2) A set of weighting factors for demolition of the different dwelling types;

and 3) A set of weighting factors for the demolition of dwellings of the different periods of construction.

2.3 Thermal Retrofit 2.3.1 This block inputs the user's estimates of home owner's insulation retrofit propensities. That is, if a house is insulated to R20 in the ceiling, what is the chance that the owner will upgrade his insulation to R28. Four heat loss areas are considered; ceiling, walls, basement, and air infiltration. Again, this is a time dependent variable which traces the behavior of the average homeowner forward in time as far ahead as 2001. The changed insulation levels are applied to the old housing stock and the improved energy needs calculated.

The output from block 2.3 includes those described under subsections 2.3.2 and 2.3.3.

2.3.2 Changed thermal representation of the base housing stock.

The housing stock broken down by thermal archetype and type of dwelling together with the percentage distribution of the archetypes for each period of construction is given. This table can be compared with that given at the start of the simulation to calculate how many dwelling have been upgraded as a result of the thermal retrofit parameters specified in 2.3.1.

2.3.3 An energy report for the base housing stock giving the changed energy demand for space heating as a result of the thermal retrofitting allows the user to calculate the savings due to insulation upgrading.

2.4 Equipment Retrofit

2.4.1 The input variables for this block are the largest single user input to the model. They consist of transition probability arrays, for each housing type, showing movement of housing stock between the different types of heating equipment. Heating equipment installed in the housing stock is described in the model by the categories listed in 2.1.1. Since there are 17 of these categories changes from one equipment type to another can be shown by a 17 x 17 square matrix of proportions. Such an array is provided for each dwelling type and for each simulation period and is given in the following table. This time series variable consists of such a large number of data points, up to 2890

through the year 2001, that projective generator programs have been written to aid the user.

2.4.2 The output from block 2.4 includes a report on the changed composition of the base housing stock by type of heating equipment. From these tables the user can determine the existing stock of dwellings by heating equipment type and also keep track of how many dwellings have converted from one fuel source to another.

2.4.3 The base energy demand is also output. This would change as a function of the different seasonal heating efficiencies of the equipment types.

2.5 New Housing

Inputs here include those described in subsections 2.5.1 to 2.5.4

2.5.1 Projections of net household formation used in this model were obtained from Statistics Canada's population model, recently disaggregated by province. These data were obtained from the Demographic Division, Statistics Canada. The net households used in the example scenarios correspond to the B series. The assumptions associated with the B series are:

a) "low" headships rates which are the same as the "High" rates used in series A until 1991 and lower thereafter such that the 1986 rate of the "High" is reached in 1991. The "High" rate is defined as 1966-1976 headship rates exponentially extrapolated to 1991 and the 1991-2001 rate is held constant at the 1991 rate.

b) The population series 3 is used (see STC 91-520)

c) The fertility rate of 1.8 for 1976 and 1.6 for 1991 and thereafter.

d) A net international migration rate of 750,000 was used together with the following series of net interprovincial migration rates:

1976-1981	1981-1986	1986-2001
40,500	48,000	47,500

2.5.2 Vacancy rates obtained from CMHC are included here to translate households into new dwellings actually built, which will exceed new households by a small percentage.

2.5.3 Data on the penetration of heating equipment types installed in houses built from 1971 to 1979 were obtained

from Ontario hydro's electrical inspection records. These data were linearly extrapolated to obtain the post 1980 equipment breakdown of the new housing stock.

2.5.4 In each period, specification of the thermal representation of houses built in that period must be made. These parameters reflect current building codes and performance measures which will become mandatory in future new house construction.

2.6 Aggregate Energy

2.6.1 This block aggregates the energy used by the many subdivisions of the housing stock and extracts a grand total, and subtotals by fuel and housing type. The aggregate energy calculations can be invoked between all the blocks in figure 2.0 to show changes in energy levels due to specific retrofits. The reports generated also subtotal domestic hot water energy needs.

2.7 The Looping Pattern

2.7.1 The model moves forward in time by five year increments starting with the five year period 1972-1976. The data input by the housing block is for 1971 and the first period of operation is the 1972-1976 period. The retrofitting and demolition variables for any time period refer to changes

that are expected to occur during the preceeding five years; that is, variables for 1976 refer to the 1972-1976 interval including 1976. Following this scheme, the model was calibrated with partial data available during the 1972-1976 and 1977-1981 thus leaving the 1982-1986, 1987-1991, and subsequent periods for the user. Naturally, the calibration period can also be used to make assertions about what has happened during the last ten years. All reporting is also done on a five year basis. The time loop indicated in the block diagram above shows where the calculations are commenced for each period.

2.8 Hybrid Heating Dynamic Load Analyzer

2.8.1 Since the energy demand calculations for space heating in the Household Model are performed on an hourly basis we have recently implemented a dynamic load analyzer into the existing framework of the space heating calculations such that appropriate base load capacity and peak load problems associated with the possible conversion to hybrid electric heating can be impacted on the residential energy demand sector.

2.8.2 The principal cause for considering a dynamic load analyzer lies in the transient nature of the annual heating requirements. For example only approximately 4% of the total annual energy requirements occur when the heating

demand is higher than 60% of the maximum. In other words most of the annual space heating energy is needed during the less cold days. In a purely electrically heated home the installed heating capacity is designed to meet the peak heating loads (normally in January, the coldest month) which occur only during a short part of the heating season. In a hybrid heating system the electrical portion could be designed to meet a little over half the annual demand yet would have an installed capacity of less than a quarter of that needed to meet the peak heating load. The electric portion of the hybrid system (installed base load electrical capacity) would be used during "off-peak" periods to avoid enhancing the existing peak loads and the supplementary oil or gas heating system would meet the heat requirements during these "peak" periods.

2.8.3 The dynamic load analyzer requires as input regional specified January design temperatures to calculate the peak heating requirements. These peaks would vary according to the size and thermal character of each dwelling type. Knowing the peak heating requirements the base capacity for the hybrid can be calculated as a proportion of this peak. Conversion rates of pre-1971 built houses to hybrid heating would be specified in the equipment retrofit input paramters.

3.0 SIMULATION DESIGN

3.1 Simulation and Forecasting

3.1.1 Time structured analytical devices such as the Household Model can be used in either simulation or forecasting mode. Simulation implies the specification of a subset of the model's exogenous parameters which reflects the user's perception of a "future which may happen" as a result of either government policies or prevailing market forces. For example, in the energy domain the model user could simulate a dramatic shift off-oil for space heating in the next decade. The user could hypothesize either a shift to gas, electricity or a combination of both. In order to measure the effect of such alternatives a "baserun" or "business as usual" run would have to be obtained to provide a bench mark against which the alternative scenarios could be compared.

3.1.2 Forecasting, however, implies the estimate of model input-parameters through either econometric techniques which reflect the response of consumer's behavior to price variations or through projective machinery such as a demographic model. The outcome of the model would constitute a 'forecast'; a "future wich is expected to happen." Forecasting is normally performed for the short term future whereas simulation exercises examine long term

structural changes in the economy. The Household Model is predominantly used in simulation mode due to its detailed input structure and articulation of major policy exogenous variables. However, it has and can be used for short-term forecasts of space heat demand.

3.2 Example Simulation Exercises

3.2.1 In order to demonstrate the simulation capabilities of the Household Model the model runs of section 5 will be used. These runs show the impact of an off-oil program on the space heating market and overall energy demand.

3.2.2 First of all a base run or 'business as usual' scenario was constructed through the specification of all the input variables outlined in section 2, The specification of the variables were chosen to be reasonable both in respect of current trends and in respect of the model's internal restrictions. That is, we have not biased it in favour of one vision of the future over another. In fact a middle of the road or average choice of the input values were used. The construction of the baserun provides a bench mark against which the variant scenario as result of the perturbation of some of the baserun's inputs can be compared.

3.2.3 The variants from the base run scenario illustrated in

section 5 were obtained by perturbing the fuel substitution parameters such that they reflected three possible off-oil futures. These variants can be compared with the baserun for oil and overall space heating energy savings. Each of the variants represents a different specification of the equipment retrofit proportions such that large scale substitution of gas, electricity and hybrid heating systems were effected.

3.2.4 Market Analysis

The aggregate impact of all the forces at work within the housing stock can be seen at each five year period in their effects on stock levels with specific characteristics. For example, the number of houses in the old stock (pre 1971) that are still being heated with oil in the future period and whose furnaces are, at that future time, oversized due to insulation retrofits can be obtained from the model's stock reports. The regional weather effects on heating equipment for both new and old stock can be investigated by using the various regional weather information available to the model through its data base. This could, for example, establish the market for heat pumps in a region specific way.

4.0 SPECIFICATION OF MODEL RUN

4.1 Common baserun and scenario variants input

4.1.1 This section outlines the inputs that distinguish the baserun scenario from its scenario variants. First of all the inputs that are common to the baserun and the variants are listed below:

1) Seasonal heating efficiencies (EFFY);
2) Demolition rates (DEMO);
3) Thermal retrofit parameters (KRET);
4) Thermal archetypes of new housing (NEWA);
5) Demographic variables (DELH);

and 6) New housing breakdown of heating equipment (PHBX).

4.1.2 The four letter acronym attached to each input type is used as a suffix identifier on DEC PDP 11-40 files. The prefix to this file identifier would either be a standard or regionally specific identifier. For example, Ontario standard demographic input data would be called ONTRDELH. A variant from this would contain a portion of the prefix together with some identifier which the user understands to signify that variant. For example using a series A demographic data obtained from the Demographic division's standard published household projection series could be called, ONAADELH. These conventions are necessary to help

keep track of a data base of input files for the household model. The perturbations and combinations of input files to create a multitude of scenarios necessitates the use of a file management system which has not as yet been implemented.

4.2 Specification of Scenario Variants.

4.2.1 The variants to the base scenario are obtained by altering the baserun equipment retrofit (ERET) parameters to produce the following three distinguishable scenario variants:

1) High gas scenario variant (HGAS)

2) High electricity scenario variant (HEEE)

3) Hybrid-oil scenario variants (HYBR)

All three variants HGAS, HEEE and HYBR were obtained by altering, quite drastically, the equipment retrofit percentages of the baserun equipment retrofit file (BASE) in periods 1981-1986 and 1987-1991.

In short we attempted to simulate what effect an off-oil government program would have in the next ten years. The specification of the ERET parameters for the 1972-81 period are of course historical, even though conversion data are not readily available. The periods 1992-2001 were the same in the HGAS, HEEE and HYBR as the BASE ERET file since most of the stock of oil dwellings which could be converted to

either gas, electricity or hybrid-oil heating have already been converted in the period 1981-1991.

4.2.2 The HGAS, HEEE and HYBR scenario variants have identical conversion rates in the two periods 1981-86 and 1987-1991. They only differ by the fuel to which the oil heated homes are being converted. These rates for the respective periods off-oil to either gas, electricity or hybrid-oil are:

1981-86 35% conversion rate

1987-91 65% conversion rate

4.3 The Hybrid Electric Furnace

4.3.1 A non-linear effect can be introduced by including the hybrid equipment in the calculations. Hybrids operate by providing all the energy needed by a house up to a certain amount by using one fuel by itself; then, when more energy is needed, it is supplied by a second fuel. The first fuel thus supplies the base load and the second fuel serves as a backup when the weather gets cold enough to outstrip the capacity of the base energy source. There are two flavors of these hybrids which differ in what happens at the changeover point:

1. the base load fuel is not used after the change over and

the entire heating load is supplied by the backup fuel;

and 2. the base load fuel continues to supply the maximum of its capibilities and the backup fuel merely fills in the gap.

4.3.2 The Household Model uses the second option in the scenarios that follow in part five. The user determines the changeover point by specifying a percentage of the a priori house design heating capacity to be supplied by the base fuel. The Household Model will support three types of hybrid at once. It also allows the fuels used to be user specified and the changeover points to be specific for type of house and hybrid type.

5.0 SIMULATION RESULTS

The results from the base run scenario and the three scenario variants are presented graphically in charts 5.1.1 to 5.4.4. These results are described in the following sections 5.1 to 5.4; each section refers to a particular class of graphical output. Associated tabular output is also given in tables 5.1.1 to 5.4.1.

5.1 Total Space Heating Energy and Fuel Mix Penetrations.

5.1.1 Charts 5.1.1 to 5.1.4 describe the impact of the baserun and three variant off-oil scenarios on the total space heating energy requirements and the resultant fuel mix proportions. There are two scales on each chart. The solid lines represent fuel mix percentages and are interpreted on the left Y-axis. The broken line gives the total space heat energy demand and is to be interpreted on the right Y-axis. Table 5.1.1 gives the total space heat energy and energy by fuel type for the BASE run and HGAS, HEEE and HYBR variant scenarios.

5.1.2 We see that there is, in chart 5.1.1, a gradual but steady reduction in fuel oil usage. This, the baserun underlies all the off-oil scenarios in charts 5.1.2 to 5.1.4. We appear to have therefore, an underlying "off-oil program" situation. This can be explained by an extant conversion

situation of oil to gas and electricity as well as few houses constructed since 1971 have oil furnaces installed.

5.1.3 Due to a program of ungrading the thermal integrity of older houses (Canadian Home Insulation Program) and the increased thermal efficiency of new houses, the total energy demand over the 25 year time horizon actually declines. In the high gas, high electricty and hybrid scenario variants, we see, of course, a much more rapid decline in fuel oil usage. The high electricity scenario gives the lowest total energy demand curve. This is due to the much higher end use efficiency of using electricity.

5.2 Ontario Housing Stock by Type of Dwelling and Period of Construction Mix.

5.2.1 Chart 5.2.1 gives the projection of the total housing stock for Ontario shown by the broken line which is read off the right Y-axis. The total housing stock increases from 2.7 million to 4.3 million, an increase of approximately 60%, despite a reduction in overall energy usage for space heating as seen in charts 5.1.1 to 5.1.4. The decline in market share of the single detached dwellings is taken up by the increases in the multiple family type housein, (apartments, row houses, and semi detached and duplexes). Table 5.2.1 gives the housing stock by type of dwelling which was used in chart 5.2.1.

5.2.2 Chart 5.2.2 shows the evolution of the old and new housing in a comparison bar chart format. Old houses refer to those constructed prior to 1971 and new houses refer to those built after 1971. By the year 2001 there are more post 1971 built houses than pre 1971 built. This implies that the overall thermal efficiency of the housing stock, which is normally attributed to more modern houses, is increasing. Table 5.2.2 outputs the pre and post 1971 housing stock for the 1976-2001 period.

5.3 Comparative Scenario Fuel Usage

5.3.1 Charts 5.3.1 to 5.3.3 show for each of the fuels, oil, natural gas, and electricity the comparative fuel usage in natural units for the baserun and the three scenario variants. In chart 5.3.1 the amount of oil saved between the baserun and the scenario variants can be gauged at each point in time. Tabular output associated with these charts is given in tables 5.3.1.

5.3.2 Also the relative saving of oil from period to period can be measured off these charts. We see that the baserun decline in oil use provides quite substantial savings without any external interventions. The natural gas and electricity charts 5.3.2 and 5.3.3 respectively show the growth in these fuels from period to period as well as intra period scenario variant changes.

5.3.3 Fuel Oil Savings

Chart 5.3.4 shows the fuel oil usage for the Baserun and the Off-oil scenario. The difference between these curves gives the savings in fuel oil over time as a result of a government off-oil program. The area under the difference curve gives the cumulative fuel oil savings over the projected time horizon.

5.4 Comparative Scenario Housing Stock.

5.4.1 The final set of charts 5.4.1 to 5.4.4 show for each of the heating equipment types: oil, natural gas, electricity, and hybrid electric oil the comparative stocks of housing in thousands of houses for the baserun and three scenario variants. These charts are almost identical in form to the previous fuel usages comparative charts. They differ in the representation of the hybrid electric oil dwellings. These housing stock charts distinguish the hybrid electric oil houses as separate equipment types, showing in chart 5.4.4 the penetration for the hybrid scenario of the hybrid electric oil furnace. In chart 5.3.1 (fuel usage chart) the oil used in the hybrid is of course added into the fuel category as is the electricity in chart 5.3.3. These stock charts are useful for analyzing the market requirements for furnaces of a particular type. For example the requirements for gas and electricity furnaces can be

estimated from charts 5.4.2 and 5.4.3.

Tabular output associated with charts 5.4.1 to 5.4.4 is given in table 5.4.1.

Figure 5.1.1

Ontario Space Heat Baserun

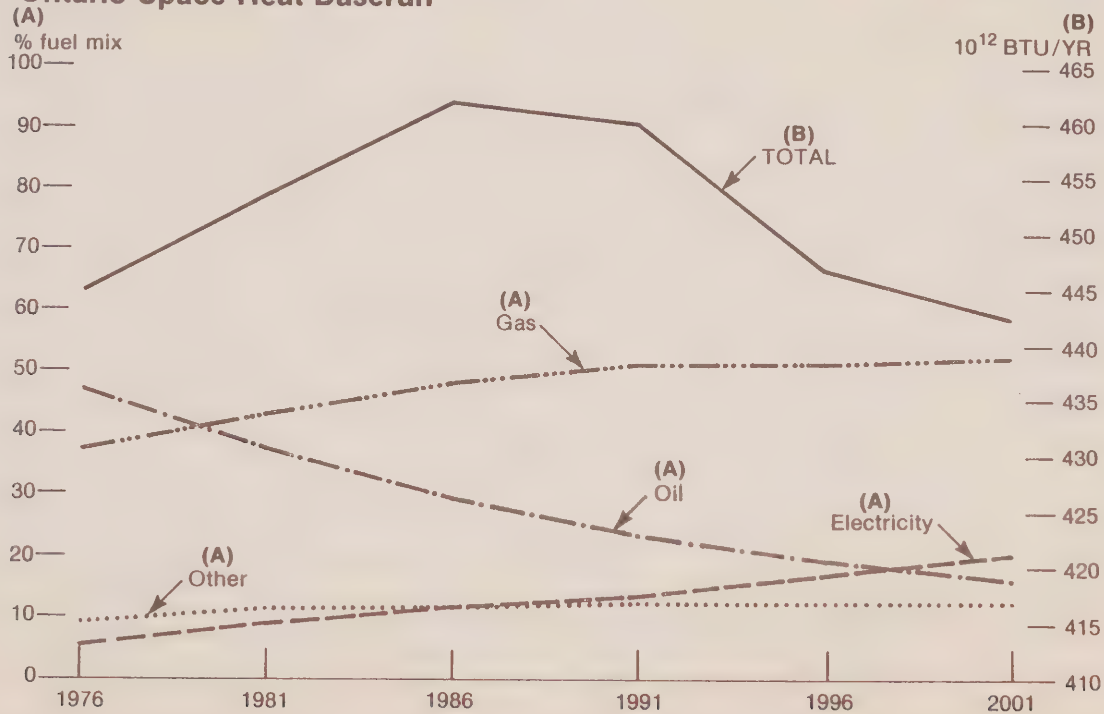


Figure 5.1.2

Ontario Space Heat High Gas Scenario

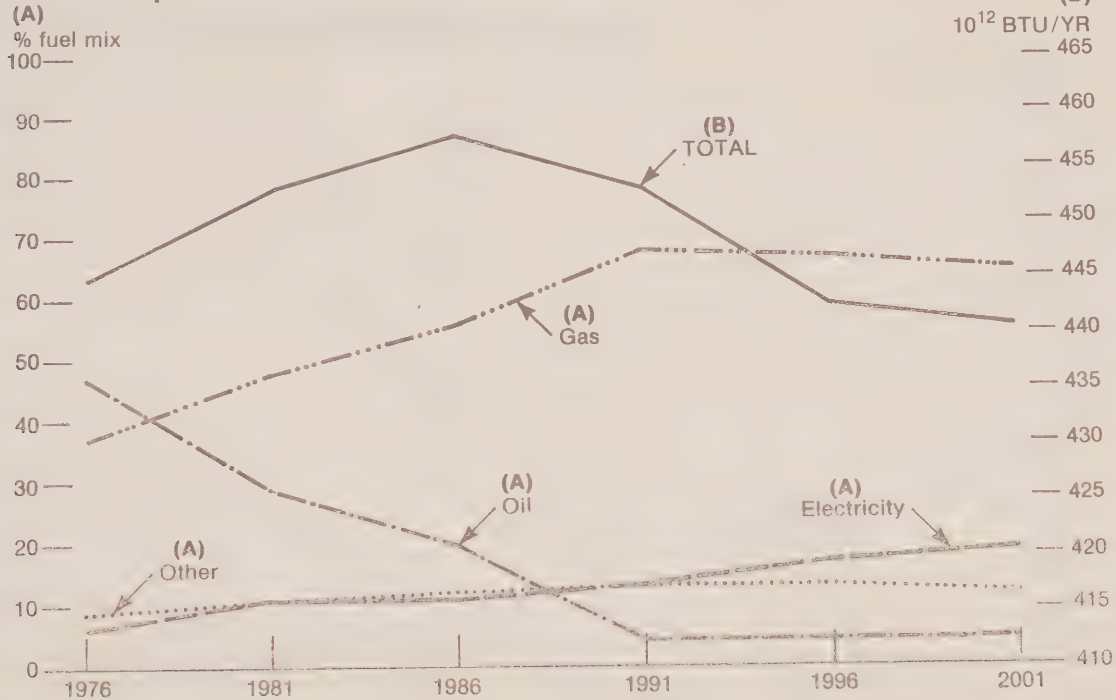


Figure 5.1.3

Ontario Space Heat High Electricity Scenario

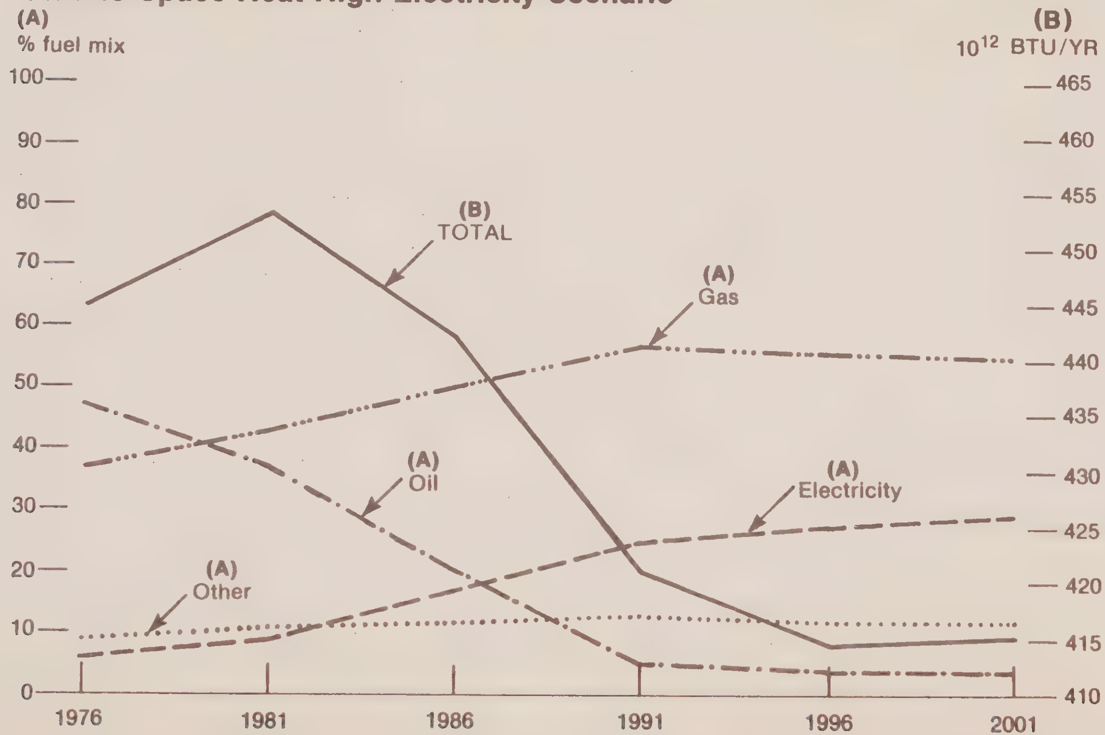


Figure 5.1.4

Ontario Space Heat Hybrid Oil-electricity

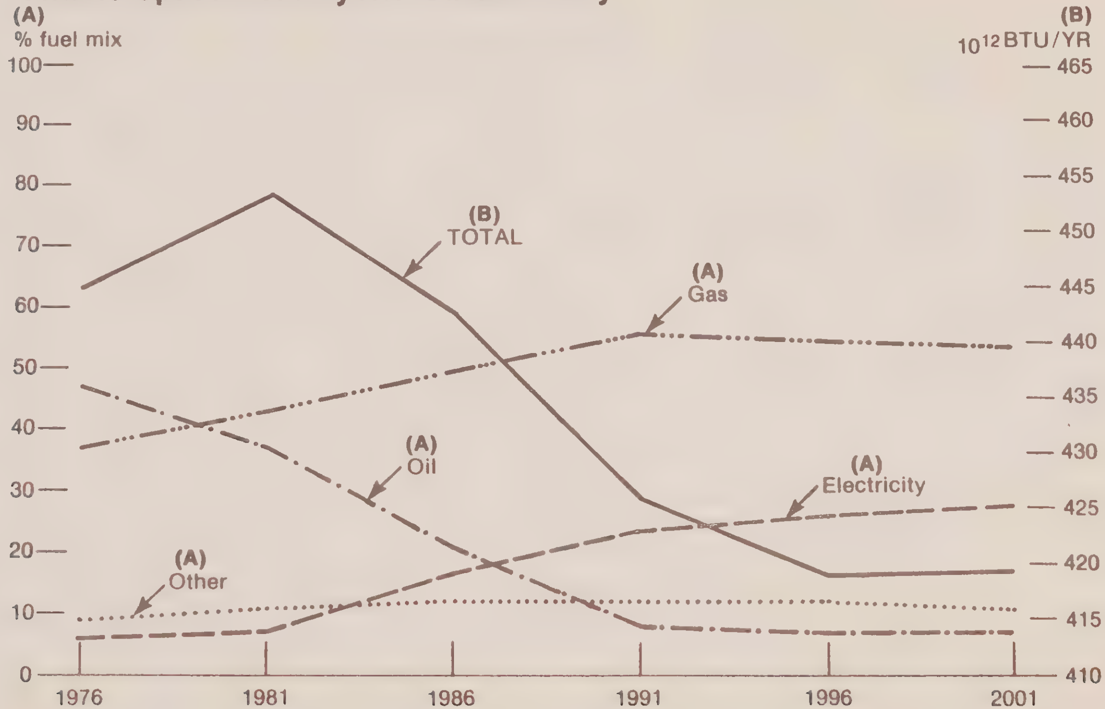


Table 5.1.1 Ontario Space Heat Energy Demand by Fuel and Total Energy 10^{12} Btu/yr. for the BASE run and HGAS, HEEE, HYBR scenarios.

YEAR	SCENARIO	OIL	GAS	ELECT.	OTHER	TOTAL
1976	BASE	208.9	166.3	28.2	41.7	445.0
	HGAS	"	"	"	"	"
	HEEE	"	"	"	"	"
	HYBR	"	"	"	"	"
1981	BASE	168.2	197.6	39.9	48.1	453.8
	HGAS	"	"	"	"	"
	HEEE	"	"	"	"	"
	HYBR	"	"	"	"	"
1986	BASE	135.8	220.9	52.5	52.8	461.9
	HGAS	90.0	259.1	52.5	56.5	458.1
	HEEE	90.0	222.5	75.5	54.1	442.1
	HYBR	93.1	222.5	74.9	52.1	442.6
1991	BASE	108.8	233.7	62.2	55.2	459.9
	HGAS	20.5	311.0	61.0	60.9	453.4
	HEEE	20.5	238.8	106.9	55.1	421.3
	HYBR	33.4	238.8	101.4	52.5	426.1
1996	BASE	85.6	230.2	76.3	54.5	446.6
	HGAS	18.5	295.0	73.6	55.8	442.8
	HEEE	18.5	231.3	114.0	50.9	414.6
	HYBR	30.4	231.3	108.7	48.7	419.1
2000	BASE	69.7	229.3	89.2	54.3	442.6
	HGAS	17.3	285.4	85.4	52.5	440.6
	HEEE	17.3	227.6	122.1	48.2	415.1
	HYBR	28.7	227.6	117.0	46.2	419.4

Figure 5.2.1

Ontario Housing Stock

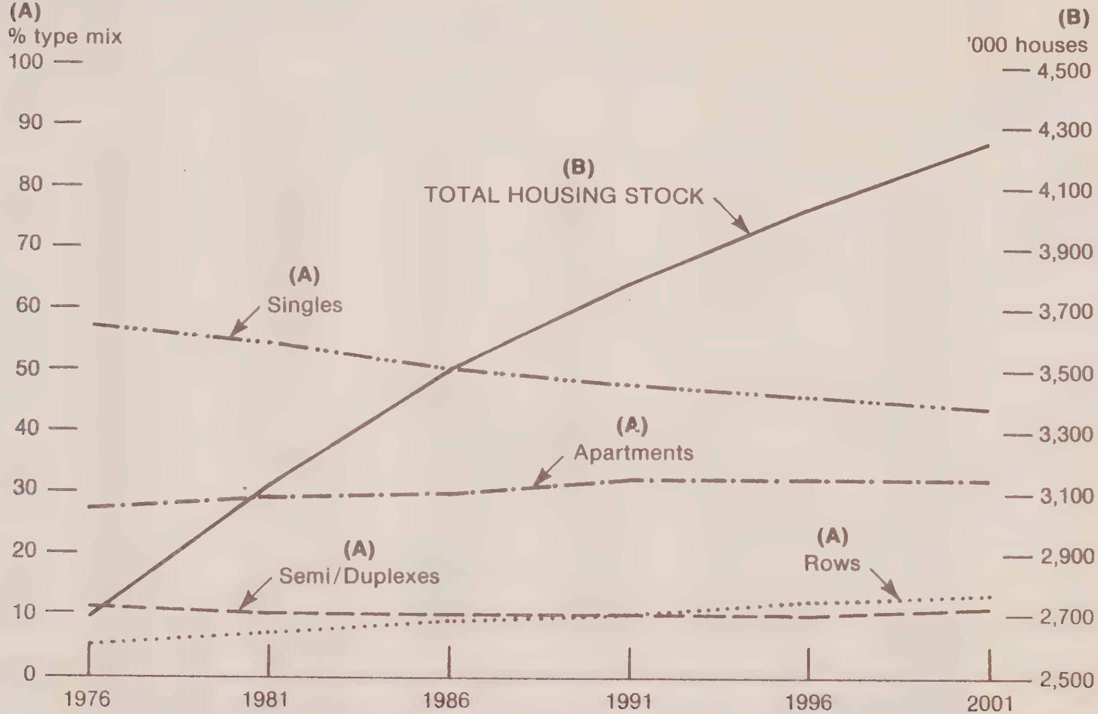


Figure 5.2.2

Evolution of Pre 1971 and Post 1971 Houses

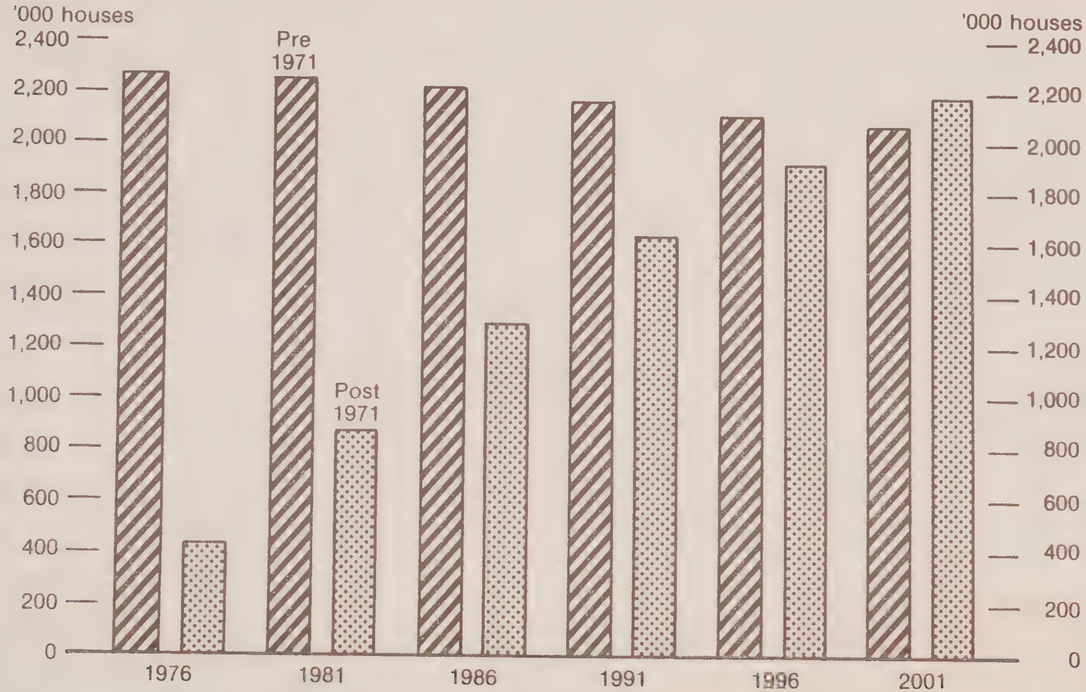


Table 5.2.1 Ontario Housing Stock by Type of Dwelling

YEAR	SINGLE	SEMI/DUPLEX	ROW	APT.	TOTAL
1976	1541854	285874	142009	725463	2695200
1981	1681589	311405	217983	903076	3114055
1986	1750080	350016	315014	1050048	3500161
1991	1821273	379431	379431	1214182	3794319
1996	1855732	403420	484104	1290944	4034201
2001	1872666	468167	553288	1361939	4256060

Table 5.2.2 Evolution of Pre 1971 and Post 1971 Houses

	Pre 1971 built	Post 1971 built	Total
1976	2276836	418364	2695200
1981	2240586	873469	3114055
1986	2202605	1297556	3500161
1991	2161072	1633247	3794319
1996	2116709	1917492	4034201
2001	2069554	2186506	4256060

Figure 5.3.1

Ontario Fuel Use Space Heat-Oil

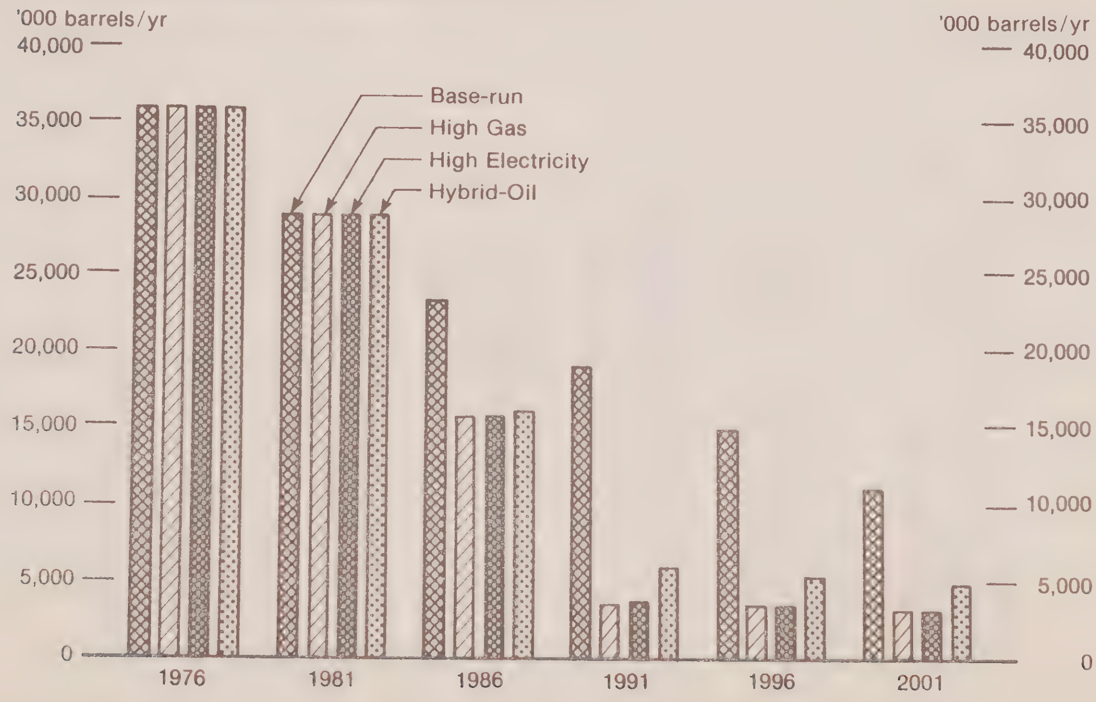


Figure 5.3.2

Ontario Fuel Use Space Heat-Natural Gas

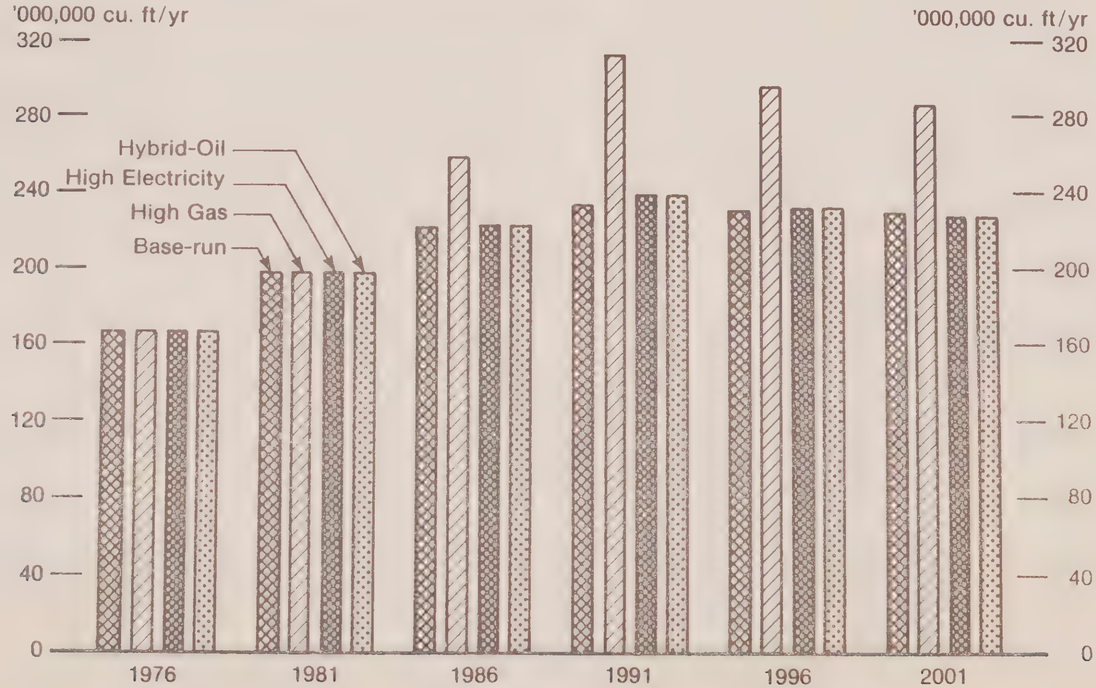


Figure 5.3.3

Ontario Fuel Use Space Heat-Electricity

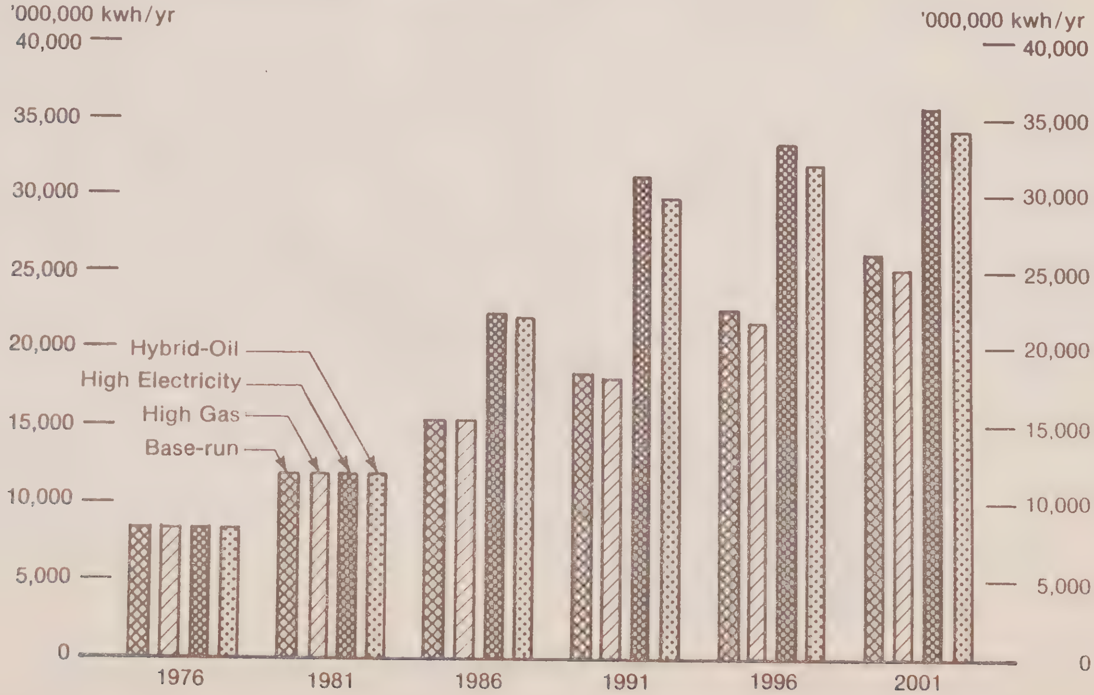


Figure 5.3.4

Ontario Fuel Oil Usage

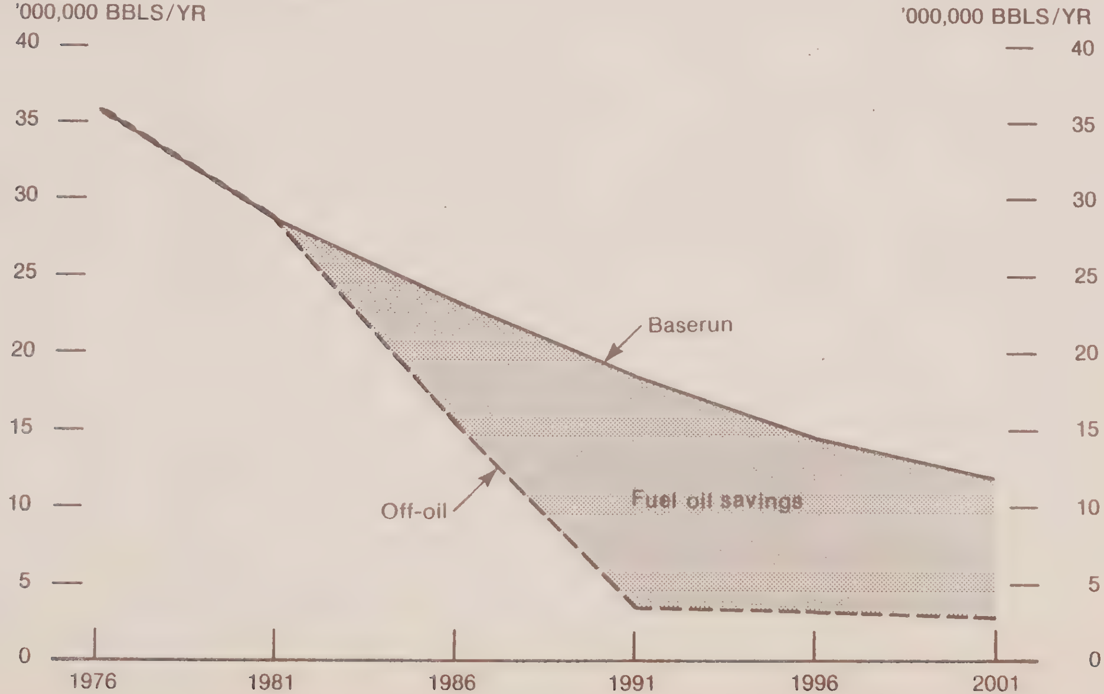


Table 5.3.1 Ontario Fuel Usage - Comparative Scenario Natural Units

YEAR	SCENARIO	OIL '000 Bbls/yr.	GAS '000,000 Cuft/yr.	ELECTRICITY '000,000 kwh/yr.
1976	BASE 1	35839	166.3	8284
	HGAS 2	"	"	"
	HEEE 3	"	"	"
	HYBR 4	"	"	"
1981	1	28861	197.6	11696
	2	"	"	"
	3	"	"	"
	4	"	"	"
1986	1	23295	220.9	15372
	2	15446	259.1	15372
	3	15446	222.5	22111
	4	15979	222.5	21950
1991	1	18662	233.7	18229
	2	3509	310.9	17887
	3	3510	238.8	31343
	4	5727	238.8	29703
1996	1	14688	230.2	22362
	2	3169	294.9	21555
	3	3169	231.3	33405
	4	5222	231.3	31867
2001	1	11969	229.3	26137
	2	2960	285.4	25040
	3	2960	227.6	35714
	4	4924	227.6	34282

Figure 5.4.1

Housing Stock Heating Fuel Oil

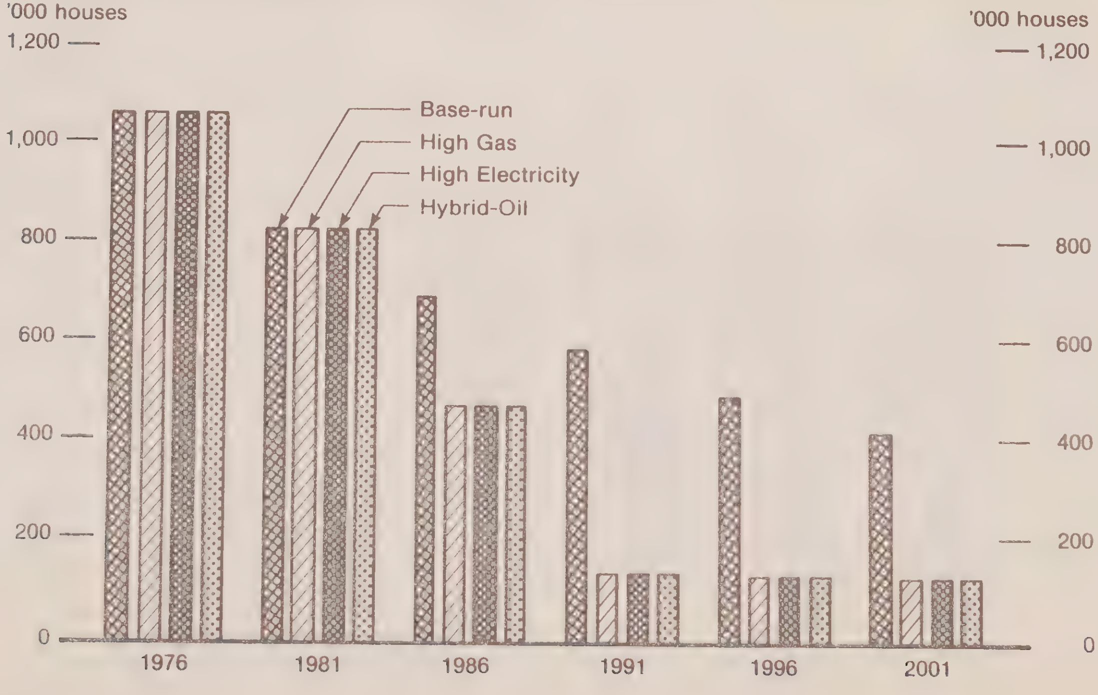


Figure 5.4.2

Housing Stock Heating Fuel Gas

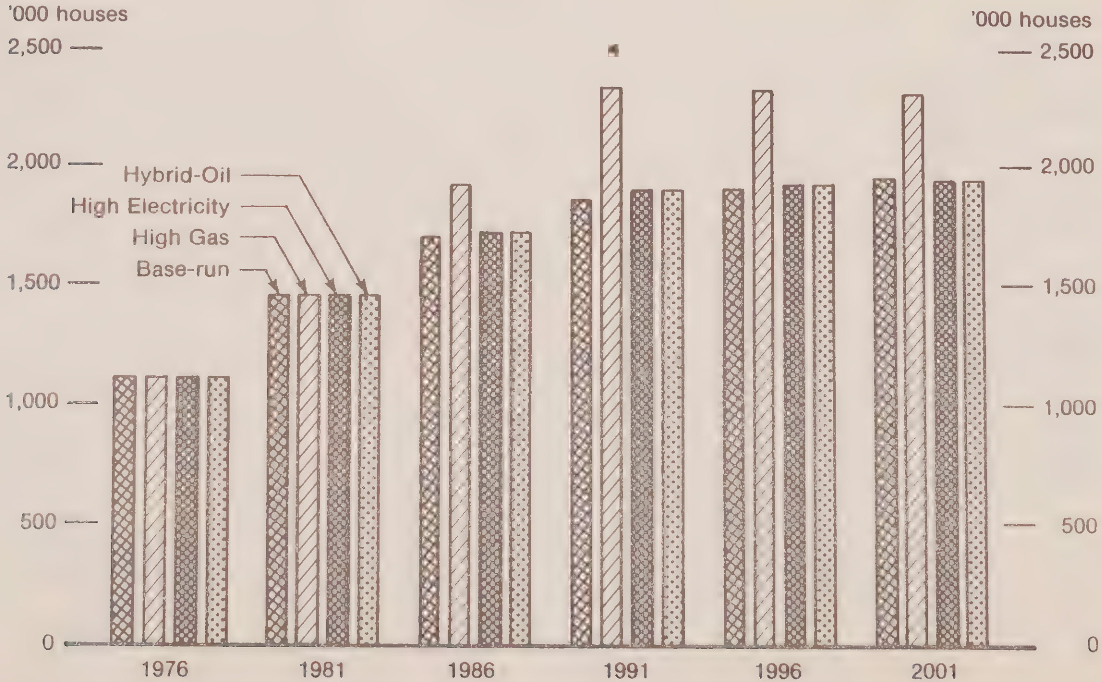


Figure 5.4.3

Housing Stock Heating Fuel Electricity

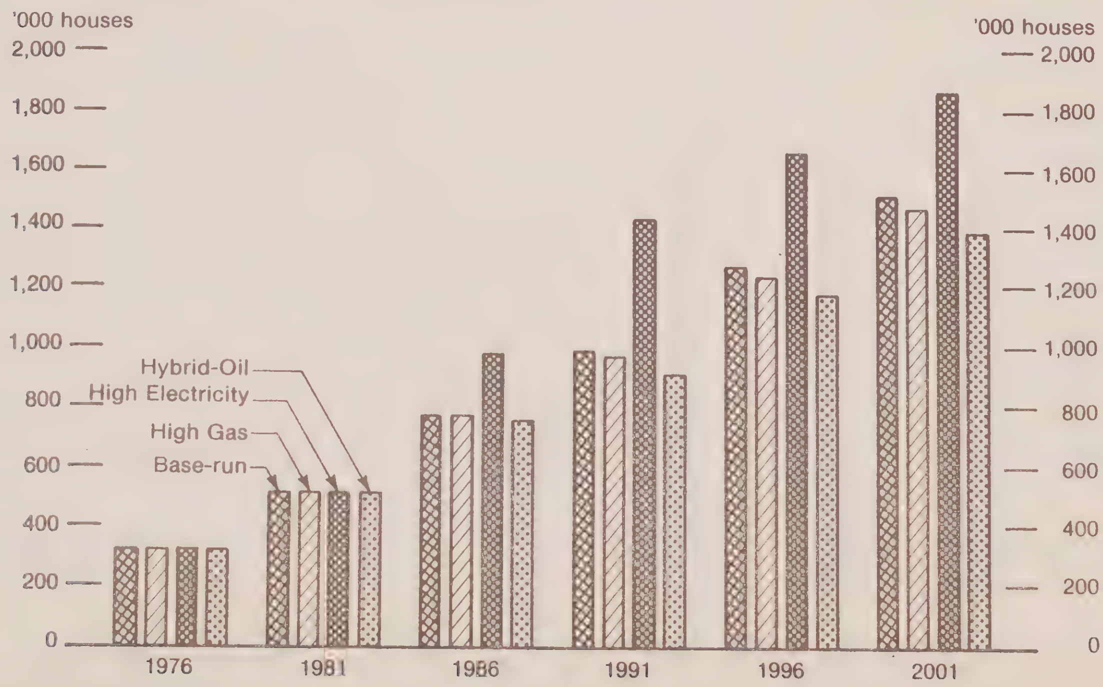
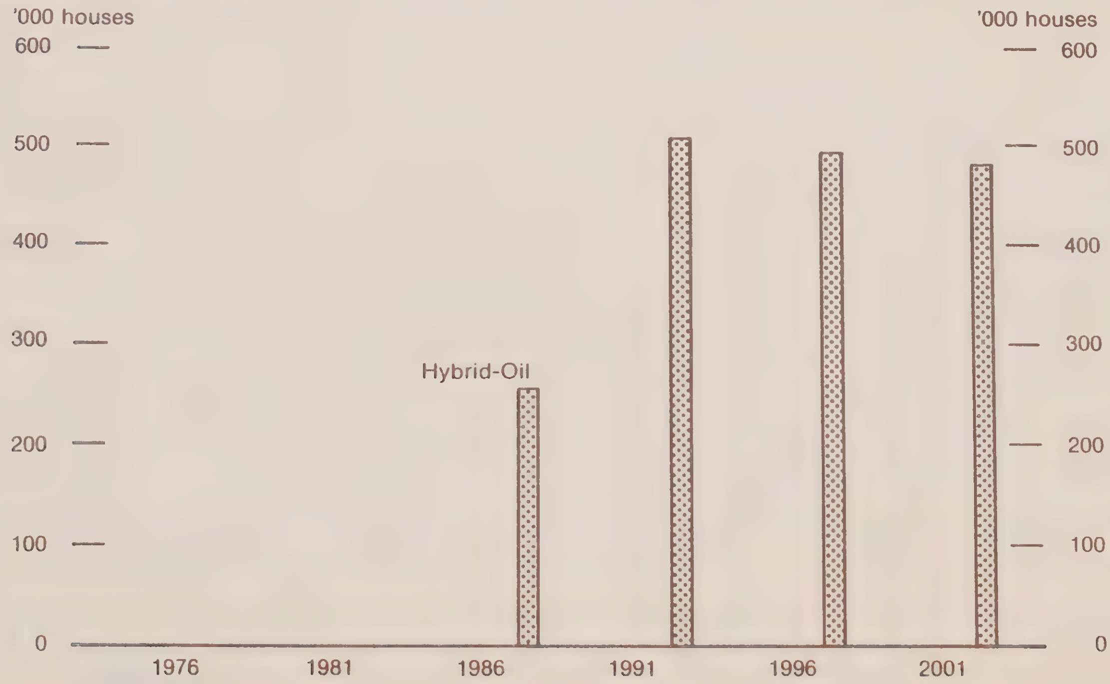


Figure 5.4.4

Housing Stock Electricity — Oil Hybrid



5.4.1 Ontario Housing by Equipment Type Comparative Scenarios

'000 Houses

Year	Scenario	Oil	Gas	Electricity	Electric-Oil Hybrid
1976	BASE 1	1057.5	1107.6	318.8	
	HGAS 2	"	"	"	
	HEEE 3	"	"	"	
	HYBR 4	"	"	"	
1981	1	821.9	1457.4	511.9	
	2	"	"	"	
	3	"	"	"	
	4	"	"	"	
1986	1	688.2	1698.5	763.5	
	2	461.9	1924.8	763.5	
	3	461.9	1719.2	981.5	
	4	461.9	1719.2	753.5	253.7
1991	1	579.5	1858.8	984.8	
	2	1277.8	2330.5	972.8	
	3	1277.9	1900.7	1433.0	
	4	1277.9	1900.7	914.3	505.7
1996	1	486.4	1910.3	1256.9	
	2	123.8	2326.8	1227.2	
	3	123.8	1927.3	1654.3	
	4	123.8	1927.3	1172.7	494.3
2001	1	412.8	1946.6	1510.3	
	2	122.4	2315.3	1468.9	
	3	122.4	1944.8	1864.5	
	4	122.4	1944.8	1393.8	482.2

APPENDIX A

A1 Common Thermal Resistance

The thermal resistances of each component of the building not including the insulation are as follows:

Ceiling (not including rafter portion).

	Thermal Resistance $(Btu/hr^{o} F)-1$
Attic surface films	0.25
1/2" gypsum wallboard	0.45
Inside surface film	0.61
Total	1.31

Exterior Wall (not including the stud portion)

Outside surface film	0.17
Face brick siding	0.42
Building paper	0.06
7/16" fibreboard	1.04
Air space	0.197
1/2 gypsum	0.45
Inside surface film	0.68
Total	3.79

Foundation Wall

8" concrete	1.11
Internal air films (still)	0.68
External air films	0.17
Total	1.96

Windows

Double glazed window	1.8

Doors

Standard external door	2.3
2 x 4" wood stud	4.37

A2 Miscellaneous

Percentage of ceiling and exterior wall which is wood stud/rafter = 15%.

Depth of basement wall below grade = 7 feet.

Depth below grade of insulation in basement = 2 feet.

Basement wall heat transfer as a function of depth below grade.

1 ft.	.41 Btu/hr sq. ft. °F
2 ft.	.222
3 ft.	.155
4 ft.	.119
5 ft.	.096
6 ft.	.079
7 ft.	.069

Basement floor heat transfer coefficient 0.023 Btu/hr °F Sq.

A value of 1.5 air changes per hour is used for apartment buildings instead of the value specified by the thermal archetypes.

Height of average room 7.5 ft.

Specific heat of air 0.075 Btu/cuft. °F.

Internal heat gain Single/Semis/Rows 3200 Btu/hr.

Apartment 2700 Btu/hr.

Internal Thermostat Setting 70°F.